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Organism

We are interested in the behavior of organisms here, particularly animals. Plants may be said to behave, because they exchange carbon dioxide and oxygen with the air and exchange excretions and nutrients with the soil, but this book is about the behavior of more mobile creatures, whether unicellular or highly complex. Before we can understand what behavior is and how it relates to the environment, we must first understand what an organism is and how it relates to its environment.

The biologist H. S. Jennings (1868–1947) studied various protozoa including amoeba. Under the microscope, this single-celled organism looks like a blob that moves by flowing and captures smaller prey like bacteria by engulfing them (Figure 1.1). If the prey moves, amoeba moves with it, overtaking it. Jennings wrote, "Amoeba is a beast of prey, and gives the impression of being controlled by the same elemental impulses as higher beasts of prey."

The first question we face is: What is an organism? Whether we are studying amoeba, rats, pigeons, monkeys, or human beings, what do all of these have in common that makes them organisms? A facile answer would be that they are all living things. That just begs the questions: what is "living"? and what sort of "thing"?

One point is clear: All organisms have a lifespan, come into existence, last for a while, and then die. A non-living thing like a chair also comes into existence, lasts for a while, and then wears

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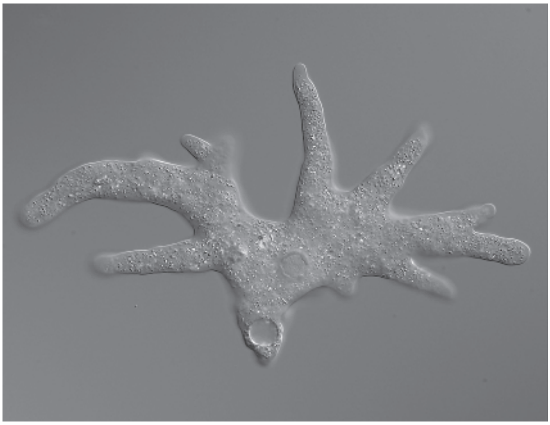

Figure 1.1 Amoeba under high resolution microscope. By SmallRex—Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=99796205.

out and disintegrates. So, something more must distinguish living from non-living.

In a word, the something more is *exchange*. While alive, an organism is constantly exchanging matter and energy with its environment. It is constantly taking in energy-rich resources, like food, water, and oxygen, and putting out waste, like carbon dioxide, feces, urine, heat, hair, scales, feathers, and dead cells into its environment. This exchange keeps the organism alive, and when it stops the organism dies.

What is death? We may understand the difference between life and death in light of the laws of thermodynamics. The second law states that in a closed system, entropy can only increase or remain the same, but never decrease. Entropy is the opposite of order or structure. When you put an ice cube in a glass of water, gradually the ice cube melts, loses its structure, and after a while ceases to exist. Its structure has broken down, and that process illustrates increasing entropy. Eventually the water in the glass comes to equal the surrounding air in temperature, reaching equilibrium, and that process too constitutes increasing entropy. Indeed, in the equilibrium state entropy increases no further, and this equilibrium represents maximum entropy.

If we apply the second law of thermodynamics to an organism, we see that death represents maximum entropy, and an organism's constant exchange of energy with its environment functions to keep the organism's state away from maximum entropy. That is to say living consists of constantly taking energy out of the environment in order to keep entropy from increasing and to spare the organism from death. Living means being constantly active.

Being constantly active is not unique to organisms; the only thing constant in the universe is change. At the longest time scale of billions of years, astronomers tell us, the universe is expanding and evolving. At the smallest time scale of tiny fractions of a second, physicists tell us, at the atomic and subatomic levels, basic matter is in constant flux. Show a geologist a rock, and you will hear a story about the processes that produced the rock and how air and water will continue to change it. Show an ecologist a mighty tree, and you will hear how it grew from a seed, developed, and eventually will die, decay, and return to the earth. Everything in the universe is in process. Scientists try to understand the processes.

Like everything else, an organism is a process. What sort of a process? Any progressive change is a process. All motion, for example, like a ball rolling, a river flowing, or a person running. Other processes are changes like growth, development, and deterioration—*any change through time*. Looked at as part of the dynamics of nature, an organism is an ever-active process, taking from the world around and excreting waste into the world around. Being alive means being continuously active.

Consider, for example, the difference between an organism and a machine—say, a car. A car can sit unused and inactive for long periods of time—weeks, or even months—and when turned on begins to run. It has suffered no damage as a result of its inactivity. No organism can do this; as long as it is alive, it must remain constantly active, constantly exchanging with its environment, if it is to remain intact. An organism, unlike a machine, has no off switch. The key difference between a bear and a car is that the bear is constantly active, fending off increasing entropy, even if asleep or hibernating.

Complex processes like a running car or an organism have *parts* that themselves are processes. The car's wheels spinning is a process and part of the car's running. Likewise, an organism, as a process, has parts too that are processes. The human body, like that of a worm, rat, or pigeon, is composed of cells that are themselves living things, processes. A cell also has many parts that are processes, such as metabolism, secretion of hormones and other chemicals, and reproducing. The cell, as process, joins together with other cells to form larger processes, such as organs, and these organs join together to form the organism.

The cells in a body perform a variety of functions and coordinate among themselves to function together. A liver cell performs different functions from a brain cell, a blood cell, or a skin cell. In their diversity, however, is also a unity, because they all work together to form the larger process that we call an organism. The liver regulates sugar, which is essential for the functioning of other cells. The brain cells regulate many other functions, particularly muscle actions. Blood cells transport nutrients, particularly oxygen, to other cells, and some blood cells also remove pathogens and dead cells from the body. The skin regulates body temperature and protects from injury. All the different cells and organs of the body function together in an integrated way, depending on one another, to keep the organism dynamic and alive.

To appreciate this intimate association and cooperation, an example in which it is not permanent is illuminating. *Slime molds* have been studied for a long while, because they form temporary organisms. They exist in two phases. In one phase the cells are separate and function independently, like amoebae. They move through a patch of soil, and each one makes its own way, engulfing bacteria and periodically reproducing by splitting in two. The population increases rapidly, sometimes doubling in a few hours. Eventually the supply of bacteria begins to run out, and then they enter the second phase. Some amoebae begin to secrete a chemical that attracts the others, and those other amoebae also begin secreting the attractant. They all join together to form a slug-like organism that contains anywhere from ten thousand to two million amoebae that all move as one. This slug makes its way to the surface, where it morphs into one or more fruiting bodies consisting of a stalk with a mass of spores at the top. The different cells differentiate and serve different functions. Some make up the stalk, and some make up the reproducing organ at the top of the stalk. The spores disperse by being eaten or by clinging to passing insects and other animals. If eaten, they pass through unaffected, and either method deposits spores some distance away in a new area. Each spore opens into an amoeba-like cell, and the separate phase begins over again.

Permanently multicellular organisms are similarly dynamic, just not in such an obvious way. Like any living thing, a cell comes into being, lasts for a while, and then dies. The cells in your body are constantly dying and being replaced by new cells. You lose hundreds of thousands of dead skin cells every day. In the course of seven years, every cell in your body is replaced (except only your teeth). Different organs are replaced at different rates. Your liver only takes a matter of months to be completely replaced. Your bones are replaced more slowly. So, the organism is not a fixed thing. It is constantly changing: a process.

Adding to the organism's inherent processes is the *microbiome*. Every organism has micro-organisms living in its digestive tract and also on its exterior. Some of these micro-organisms are parasites, but many actually live in harmony with their organism, and many contribute to the welfare of the organism in major ways. Examples abound. Termites would be unable to digest wood without bacteria in their guts that break down the cellulose. Similarly, ungulates like cows depend on bacteria in their stomachs to digest grass and other vegetable matter. The truth is that human beings could not survive without the micro-organisms in our guts and on our skin, because they are both necessary for digestion and to protect the organism from harmful bacteria that would cause infections. For example, bacteria in our gut break down dietary fiber into small molecules that can be absorbed and utilized, and other gut bacteria help synthesize vitamins B and K. Some bacteria in the vagina produce hydrogen peroxide and lactic acid, which suppress harmful bacteria. This mutual interdependence is known as *symbiosis*.

These micro-organisms are so essential to the functioning of the organism that they may properly be considered parts of the organism. So, then just what, exactly, is the organism? All the cells in the body share the same DNA, the same genetic material. The microbiome contains entirely different genetic material. Yet all this varied genetic material functions together to keep the organism alive and intact. In all that diversity that all functions together, the body is only a part. Like the body's cells, the microbiome functions in coordination with all the other processes in the body to keep the organism alive and away from maximum entropy, or death.

To appreciate the mutual benefits of symbiosis and its dynamic nature, an example in which the association with the microbiome is temporary may be instructive. The Hawaiian Bobtail Squid has been the object of study for this reason. It lives in the ocean at moderate depth. If a predator should attack, the predator would most likely come from below. The squid remains hidden during the day and comes out at night. It would be outlined against the light of the moon and stars above and easily seen. At night, however, the squid enjoys the companionship of a large colony of bioluminescent bacteria on its underside. An organ on its underside is conducive to holding the bacteria, probably the result of selection for mutual benefit (Figure 1.2). The light from the bacteria serves to confuse predators below, because the squid is less visible against the light above. As dawn

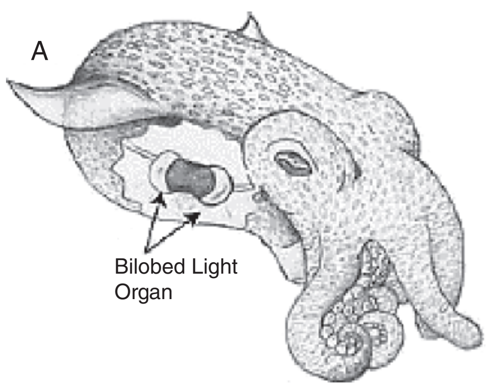

Figure 1.2 Drawing of a Hawaiian Bobtail Squid, showing the organ that houses the luminous bacteria. Reproduced from Jones, B. W., and Nishiguchi, M. K. (2004). Counterillumination in the Hawaiian Bobtail Squid *Euprymna scolopes* Berry (Mollusca: Cephalopoda). *Marine Biology, 144* (6), 1151–1155. Reprinted with permission of Springer Nature.

comes, however, the squid flushes out most of the bacteria, goes dark, and hides. The bacterial colony regrows during the day, and is operational again when night comes.

Now, we may wonder just what is the organism that we call the "Bobtail Squid"? It isn't just the body of the squid, because the bacteria function to keep the squid alive while they have a comfortable home on the squid's underside. They seem to be just as important to survival as many cells that share the squid's DNA. Yet, they come and go in a cyclic fashion, and we are driven to the conclusion that this cycle is also part of the squid as process.

Cycles like the squid's bioluminescent cycle are the rule, however, not the exception. The cycles in a human body are just not so obvious. Every day the bacteria in the gut multiply and are expelled in feces, and then multiply again. The replacement of cells in the body is another such cycle. An organism is an ever-changing dynamic process. In the next chapter we will consider how the organism's behavior is part of that process.

Further Reading

Bonner, J. T. (2009). *The social amoebae: The biology of cellular slime molds*. Princeton University Press. A book-length discussion of research on slime molds.

Jones, B. W., & Nishiguchi, M. K. (2004). Counterillumination in the Hawaiian Bobtail Squid *Euprymna scolopes* Berry (Mollusca: Cephalopoda). *Marine Biology*, *144*(6), 1151–1155. A study of the Bobtail Squid's remarkable symbiosis with bioluminescent bacteria.

Nicholson, D. J. (2018). Reconceptualizing the organism: From complex machine to flowing stream. In D. J. Nicholson & J. Dupré (Eds.), *Everything flows: Towards a processual philosophy of biology* (pp. 139–166). Oxford University Press. This chapter lays out the concept of the organism as process.

Nicholson, D. J., & Dupré, J. (2018). *Everything flows: Towards a processual philosophy of biology*. Oxford University Press. This edited volume kicks off a serious exploration of process ontology.